STUDY OF CURRENTS IN THE EASTERN PART OF THE BERING SEA WITH DOPPLER SONAR

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Introduction

In 1990 TINRO's R/V Novokotovsk has fulfilled two surveys in the Bering sea: ichtioplankton and trawl. The first was fulfilled in April 9 – May 12 in the Eastern part of sea shelf and the southeastern part of the Aleutian basin (172 stations). The second was fulfilled by bottom trawls in May 25 – July 13 on the shelf of Economic zones of the USA and USSR (283 stations). Surveys were accompanied by an acoustic probe with echosounder Priboi–101 (USSR), CVS-881B (Japan) and echo integrator SIORS (USSR).

Different types of current hydroacoustic profilographs (coherent, incoherent and correlation Doppler systems) are used in the world oceanographic practice for more than 20 years. During this time limitations were developed and published in details, it was pointed the possibility of application of specified systems to measurement of current velocity profiles and their advantage to corresponding mechanical systems (Aksenov & Tarasuk, 1989).

During the Bering Sea pollock complex survey in spring-summer 1990, besides standard hydrological and trawl-acoustic surveys, there were conducted the measurements of currents characteristics. To measure the velocities and directions of currents it was used the Sonar Current Indicator (CI-30), working at frequency 130 kHz (Doppler…, 1980, FURUNO…, 1983). The place of device antennas set was on the bottom of vessel hull, near the keel. Thus, antennas sinking is possible to consider to be approximately equal to draft of vessel, 5 m (according to loading of vessel by fish, draft increases to 6 m approximately to the end of trawl survey). Three leaning beams of antennas of device are in 120° angle in relation to each other, in accordance with antennas strengthening. Along with this one of beams is directed at horizontal plane forward, to bow of vessel.

Currents were measured at horizons of 7, 30-55 and 80-207 m during the period of the greatest stability of vessel course in realization of trawl stations.

Pulse length and thickness of layer, from which echo signal is analyzed, is 10 m. Along with this center of the first horizon was at the depth of 7 m. Measurements were carried out for 5 impulses. Integral means of velocities and directions of currents were determined during 1, 2 and 5 minutes with intervals of their registrations in every 15 s.

The level of a signal in the sea was sufficiently high as a rule, and the corresponding alarm information about possible error on display of device was not received. The ensemble of realizations, from 10 to 400 in numbers was brought in to personal computer (PC) and was postprocessed (calculations and drawing graphs, spectral analysis (Vasiliev & Gurov, 1998). Horizons of measurements were established in three numbers. Intermediate horizon was established, as a rule, in the middle between upper (7 m) and lower horizons (0.75 depths of place, but not close to the bottom, in order to avoid the processing of ground signal). Operator did not change the depth of upper horizon, as a rule, during all the survey.

Although the discreteness of observations by Doppler sonar was depending on regime of hauls and therefore was variable within a twenty-four-hour period, in general these observations were produced with time intervals from 1 to 6 hours. Since it was selected the regime of measurements during sufficiently low velocity of vessel: 3 - 4 knots, sufficient effect of air bubbles under bottom of vessel was minimal. Consequently, it is possible to exclude the possibility of interference of sound waves on bubbles. At primary treatment, data were filtrated and false means were excluded out of a consideration. This was related to big peaks of means not packing in general course of a curve.

Signals from vessel gyrocompass were introduced to CI-30 input over AD-10 Analog-to-digital converter of signals. It allowed automatically to transform relative values of current directions to geographic north.

Geographic coordinates of Loran-C system were input into PC for further coinciding with current measurements data.

Errors of Measurements

Experimental errors are divided into accuracy (systematic errors, depending on an influence of physical effects) and accidental (statistical) errors (Kempion *et al.*, 1979). We will consider these errors of our measurements of current velocity.

The principle of an action of Doppler Indicator of Currents consists of difference definition of two identical Doppler devices means. One of these devices fulfills measurements of absolute velocity of vessel, but other one measures relative velocity on echo signals of water volume. In accordance with principle of action it is possible to differentiate possible errors of a measurement of velocity of current into the next groups (Bogorodski *et al.*, 1984): errors descending from influence of vessel-carrier, a media of a propagation of hydroacoustic signal, methodical and apparatus errors.

CI-30 apparatus error is determined by the next image: ± (2% by vessel speed +0.2 knot) (Tesler, 1983). The error of measurement of current direction is determined as ±3.5° (FURUNO…, 1983). For a reduction of errors of current velocity measurement we fulfilled measurements at a minimum velocity of vessel movement: during hauls, when this movement was establishing. Moreover, measurements were avoided during vessel rolling and pitching tosses. As we see (Fig. 1) the distribution of these errors differs from the normal one evidently because of influence of vessel velocity (in accordance with preceding mention).

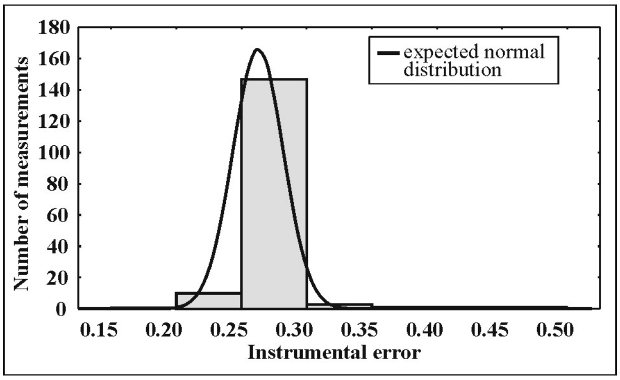

Fig. 1. Instrumental errors distribution of current velocity measurements

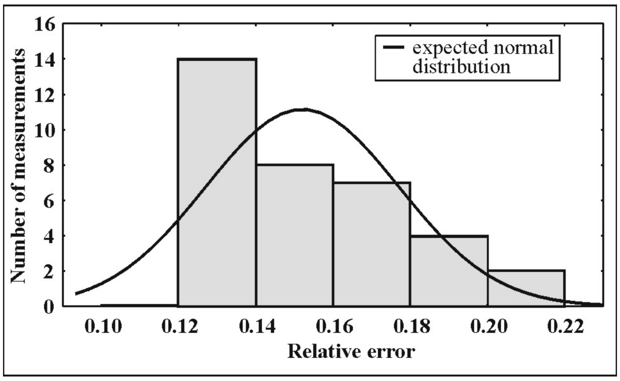

Fig. 2. Relative errors distribution of current velocity measurements

Tool preciseness of vessel coordinates definition with Loran-C receiver-indicator (Shabalin *et al.*, 1980) made 0.01 minute of geographical coordinates (GFC).

Calculated accidental, standard errors of measured current velocities changed from 0.02 to 0.05 for 10 realizations and from 0.004 to 0.06 for 35-40 realizations. As an example, here is represented a graph of relative errors distribution of current velocity measurements at one of the stations (Fig. 2).

As a result of conducted analysis it is established that fundamental contribution into general accumulated error contributes instrumental error while accidental error is by one-two order less.

Results and discussions

Many oceanologists (Kamenkovich *et al.*, 1987; *etc.*) presently established that oceanic movements of synoptic and planetary scales look like the complex of the tidal, eddy like, wave and quasi-stationary (average) compiling currents, which interact with each other exchanging energy, entropy, hydrochemical, hydrobiological and other properties of water masses.

Traditional method of calculations of geostrophic currents according to thermohaline surveys, during decades applied in TINRO and other marine research organizations, does not enable to allot foregoing components of movement of waters, though it brought extremely much information about ocean dynamics.

Appearance of a new technology in any field of knowledge generally brings establishment of new information about researching phenomenon and processes in nature.

Application of Doppler hydroacoustic measurers of currents is realized in TINRO in expedition aboard the R/V Novokotovsk for the first time in 1990 in the Bering sea. In 1991 R/V Miller Freeman (USA) produced analogous observations (Cokelet *et al.*, 1996).

Technology of production of observations by Doppler measurer (ADCP and CI-30) in these two expeditions differed. In Russian expedition Doppler observations were carried out in the period of hydroacoustic-trawl surveys with 20 to 40 miles step in slope and shelf waters (Fig. 3). In American expedition observations were carried out at 11 oceanographic sections. The horizons of measurements in those expeditions were different. Despite that measurements were made by different methods, study of earlier unknown properties of current fields of the Bering sea brought indisputable benefit in both expeditions.

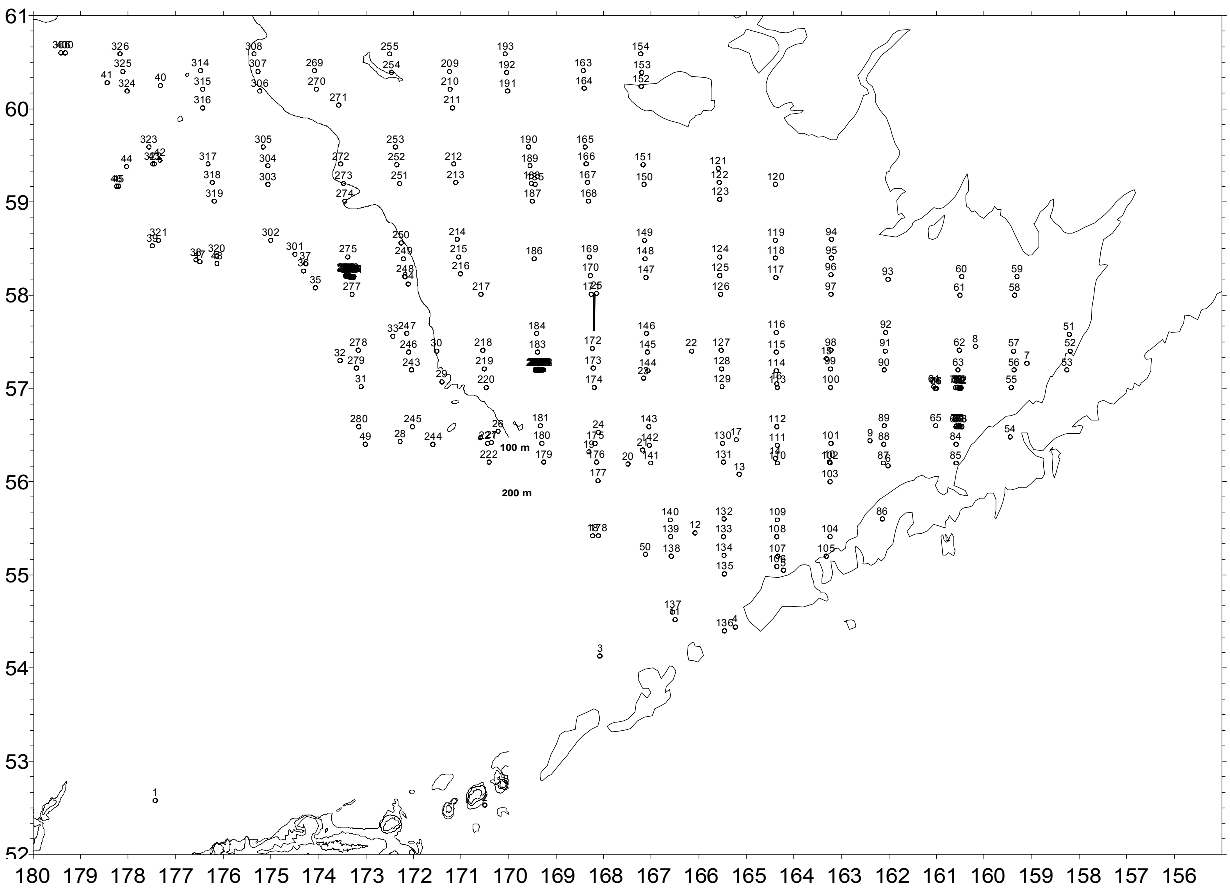

Fig. 3. Haul and CI-30 stations distributions in the Eastern Bering Sea (EBS) (R/V Novokotovsk, 1990)

Since upper quasi-homogeneous layer of sea is under the constant influence of atmosphere, meteorological conditions in near surface layer are briefly considered. Direction and velocity of near surface wind are considered the most important parameters in wind current generation. These characteristics were measured 4 times per a day during the expedition.

The synoptic maps analysis showed that in May it was observed the shift of center of Aleutian depression to Bristol Bay. Along with this Hawaiian maximum achieved the southern part of the Bering Sea with the pressure maximum 1030 mb in periphery. Average month surface pressure in May in the south-eastern Bering Sea made 1004.5 mb, that was lower than climatic norm (1010 mb). Eastern winds predominated (65.7%). Quantity of storm winds did not exceed 7.5%, in calm conditions – 5.3%. The month wind velocity mean in May compiled 7.2 m/s at the climatic means for this period 5-8 m/s.

In June, as at the end of May, cyclonic activity in atmosphere was a little higher than climatic norm. Trajectories of cyclones had NE direction with the following fixing in the region of the Eastern Aleutian Islands and the Southern Alaska. The pressure minimum in zone of Aleutian Depression compiled 985 mb. Anticyclonic activity was characterized by some reinforcement of Polar anticyclone, maximum pressure at periphery of which achieved 1025 mb. Along with this the Hawaiian maximum displaced to the South, achieving Aleutian Islands just during two days (July 26-27 1990). The monthly near surface pressure mean compiled 1009.6 mb (1011-1013 – climatic norm). This month it was observed the Western winds predominance (60%). Average velocity of wind compiled 5.9 m/s, that corresponds to climatic norm (5-7 m/s). It predominated force 1-4 wind by Beaufort scale (63.4%).

In July the center of the Aleutian Depression located between Bristol and Alaskan Bays with its outflow to the continent. The activity of high pressure centers descends. Minimum pressure in the center of Aleutian depression compiled 992 mb and its effect on the shelf water predominated. Monthly pressure mean in July compiled 1008.3 mb, that was considerably lower than climatic norm (1015 mb). In July it was again observed the predominance of Eastern winds (43.3%). Maximum velocities of wind did not exceed 12 m/s, at monthly mean value 4.4 m/s. Predominating 91.6% winds were weak 1.4 (Beaufort scale) (Pashenko, 1990).

The main reason of currents in upper layer of Ocean is immediate transmission of an impulse from wind to water. Therefore it is considered the inside month dynamics of wind effects on sea surface in details. Graphs of the spatial-temporal variability of wind speed and direction and wind currents at trawl and hydrological survey areas during May-July 1990 are represented in Fig. 4 and Fig. 5. The large-scale fluctuations of directions and velocity of near surface wind (Fig. 4) were generally conditioned by passage of Cyclones and atmospheric Fronts. Predominant period of changes of wind direction is 1-2-days. 3 –day, 4 and 6 day periods were imposed on these cycles, reflecting passage of large-scale anemobaric systems. Fluctuations of wind velocities were not coherent with wind direction oscillations and occurred, as a rule, with displacement of about 1 day, though separate coincidences of phases were also registered. This result is not the trivial. It is impossible to reveal this phenomenon on synoptic maps due to high scale of this maps and, as a rule, absence of data with such high discreteness above any marine areas. However, it is not erroneous.

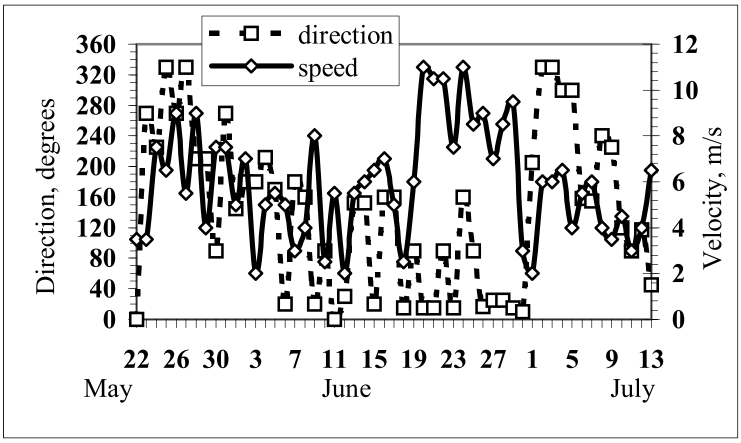

Fig. 4. Wind velocity and direction in the Bering Sea area in May, June and July 1990

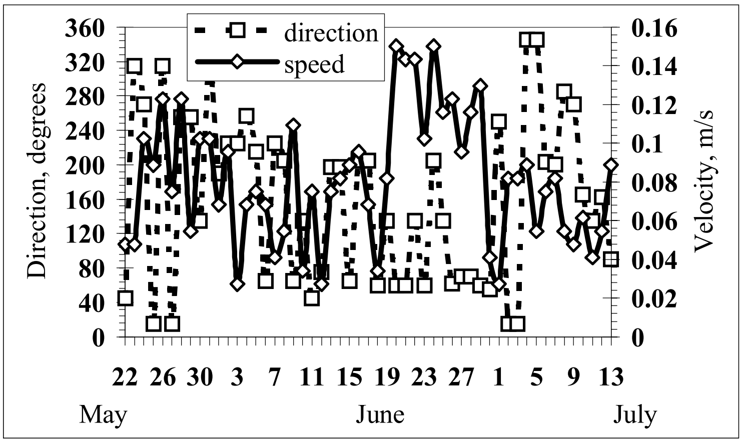

Fig. 5. Velocity and direction of wind currents in the Bering Sea in May, June and July 1990

Previously (Kouchmen *et al.*, 1979) it was informed that in the Northern Bering Sea, at Walls Cape there were existed wind oscillations with the same period, however, its regional length was not established. Authors suppose the presence of local atmospheric disturbances, comparable by scale with current fluctuations. In given case these fluctuations were discovered along the all shelf zones of Russia and the USA and obviously, they aren't of local character, as it is marked by American oceanographers. Drift currents fluctuations in near surface layer repeated the described wind direction and velocity fluctuations with small exceptions (Fig. 5). Range of change of wind currents velocities was from 0 to 0.16 m/s with predominant velocities 0.03-0.11 m/s, that is comparable with American measurements of currents by recorders Geodyne Mode-102 in offshore zone of the USA (Burch & Scarlet, 1977).

In field of pressure the quasitwo-day changes were observed only in the beginning of the second decade of July, fluctuations with the period from 4 to 9 days predominated, that corresponds to synoptic scale variability. Such oscillations of pressure are known above the different regions of ocean (Abramov, 1978).

Fourier analysis (Vasiliev & Gurov, 1998) conducted separately by data of every out of three months showed that energy spectra reflecting the greatest amplitude of oscillations of wind direction and velocity have one peak in May (Fig. 6) corresponding to period of 2.6 days (Bristol Bay).

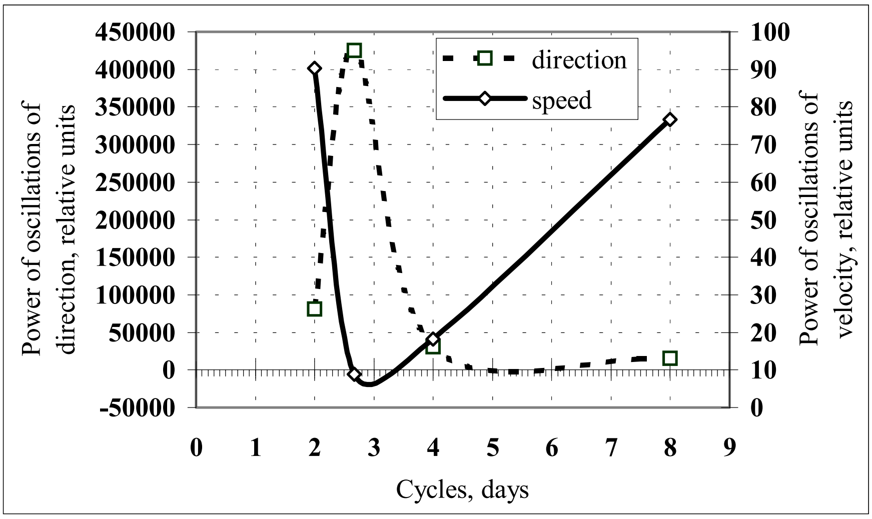

Fig. 6. The cyclogram of wind velocity and direction in the Bering Sea in May 1990

In June, during the period of works on the central American shelf, the greatest amplitudes were observed during the periods of 2.9 days (sharply expressed spectral peak), secondary low amplitude periodicity was during the periods of 2.2; 3.5; 4; 5.2; 6.4 and 10.6 days, Fig. 7.

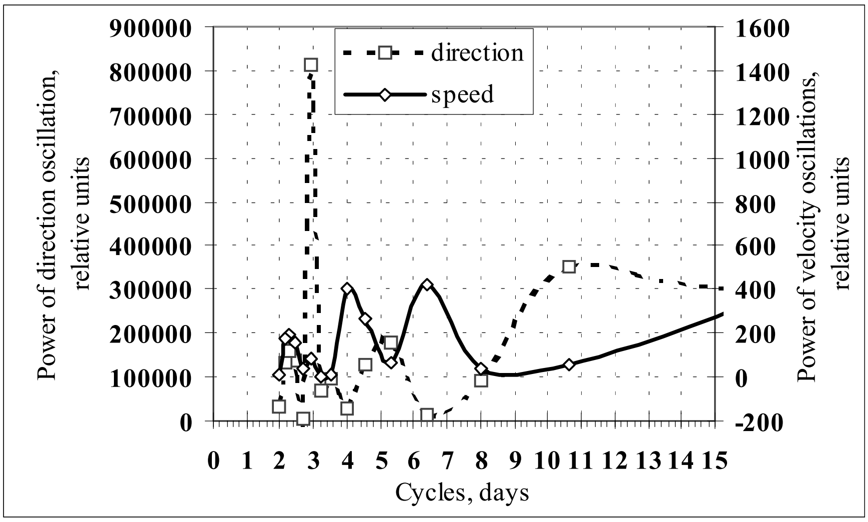

Fig. 7. The cyclogram of wind velocities and directions in the Bering Sea in June 1990

In July, during the period of works on the Russian shelf of the Bering Sea, high amplitude spectral peaks existed during 8-day period, low amplitude - during the period of 2.6 days (Fig. 8).

The cyclogram analyses show the heterogeneity of atmospheric disturbance on the shelf of the Bering Sea and make by concrete in our imagination the regional high frequency fluctuations in near the Earth atmosphere above the NW, central and eastern part of the Bering Sea.

Directions of currents in near surface layer differed much greater by a stochastic, as it is known from publications, especially on averaged current schemes. An eddy structure of currents of different scales predominates, alternating with mesoscale meandering flows.

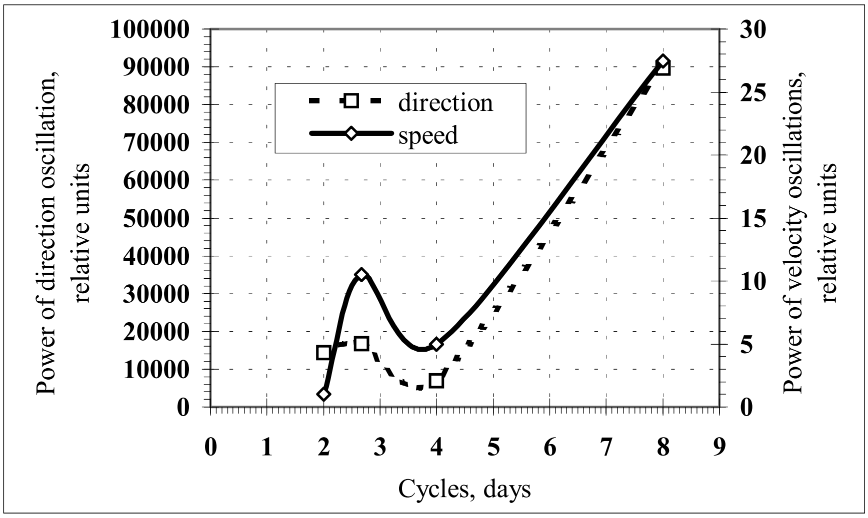

Fig. 8. Cyclogram of wind velocity and direction in the Bering Sea in July 1990

In figurative presentation the current scheme reminds more the picture made from the space satellite with obvious chaotic flows. However, the observation of mushroom like current structures on vector field with such rough discreteness is hardly probable.

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